99P2204

B3

PATENT SPECIFICATION

(11) 1 530 602

1 530 602

(21) Application No. 41988/75 (22) Filed 14 Oct. 1975
(23) Complete Specification filed 4 Oct. 1976
(44) Complete Specification published 1 Nov. 1978
(51) INT CL² H03D 3/06
(52) Index at acceptance
H3A 2Q 3N 4BX 8F
(72) Inventor IAN ALISTAIR WARD VANCE

(19)

(54) DEMODULATOR FOR FM SIGNALS

(71) We, STANDARD TELEPHONES AND CABLES LIMITED, a British Company, of 190 Strand, London, W.C.2., England, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a demodulator for frequency modulated signals.

According to the invention there is provided a demodulator for frequency modulated signals comprising local oscillator means for providing first and second signals in phase quadrature at the centre frequency of the frequency modulated signal, first and second mixing means for respectively mixing the frequency modulated signal with the first and with the second local oscillator signal, means for low pass filtering each of the outputs of the first and second mixing means, means for amplifying each of the outputs of the low pass filtering means to a constant level, means for differentiating each of the outputs of the amplifying means, means for coupling the output of each differentiating means and the input of the other differentiating means to a multiplying means, and means responsive to the difference between the outputs of said multiplying means to provide a demodulated audio signal.

The invention will be described with reference to the accompanying drawings, in which:—

Fig. 1 is a block diagram of a FM receiver embodying the invention;

Fig. 2 is a block diagram of an integrated circuit realisation of the receiver with associated off-chip components; and

Fig. 3 illustrates an alternative arrangement for obtaining local oscillator signals in quadrature in the general circuit of Fig. 2.

The frequency modulated RF input signal is applied to two mixers, M_1 M_2, which are fed with quadrature signals from a local oscillator LO running at the signal frequency making the IF zero frequency, the two sidebands of the signal being folded over on each other at baseband and extending in frequency from DC to the single sideband width of the original signal. The mixer outputs are low pass filtered by filters LP1, LP2 with some bandwidth $f\delta$ equal to the expected maximum deviation of the input signal from the local oscillator frequency. Thus at the output of the filters LP there are two signals in quadrature as indicated, where $\delta\omega$ is the instantaneous frequency difference of the input from the local oscillator.

The filter outputs are amplified by amplifiers G1, G2. These main amplifiers are automatic level control (ALC) amplifiers with their own detectors DET1, DET2, and feedback. Thus the later parts of the system have a standard level of signal (or noise) with which to work, and permit the receiver to have a large working signal range.

After amplification the two signals are differentiated by differentiators D1, D2, giving terms with amplitude/frequency slope and a further quadrature phase shift. These differentiated signals are then cross coupled with the undifferentiated signals at two four-quadrant multipliers M_3 M_4, which perform the linear multiplication of the two input signals and produce outputs of:—

$$a^2\ \delta\omega\ \cos^2\ \delta\omega$$

and

$$-a^2\ \delta\omega\ \sin^2\ \delta\omega \text{ respectively.}$$

Subtracting these in a differential amplifier DA gives an output of $a^2\ \delta\omega$ which is a voltage proportional to frequency deviation. That is, the whole system behaves as a frequency discriminator.

The sensitivity of this circuit to variations of block parameters is low. For example, if an exact 90° phase shift is not obtained, then a reduction in gain is all that occurs (proportional to cos ϕ—the difference from 90°)—no spurious products are generated. This is due to the symmetry of the circuit and the cross coupling between the two sides. AFC can be applied to the local oscillator from the output in the usual way.

The lack of tuned elements makes this

receiver ideal for integration and hence microminiaturisation. As will be described, the number of off-chip components is low.

Fig. 2 shows the block diagram of an integrated circuit version of the receiver and associated off-chip components. Where appropriate the same references have been used as in Fig. 1.

The performance of the mixers M1 and M2 to which the input signal is applied largely determines that of the complete equipment. They should have low loss, good strong signal handling properties and preferably require little local oscillator drive. The diode quad doubly balanced mixer is an optimum for this application. This requires the use of a differential RF stage including a RF amplifier RA to give a balanced drive to the mixer stage, including amplifiers MA1 and MA2 in an integrated form and balanced drive from the oscillator. A major advantage of this is that the feed through of the local oscillator back to the input is very low, especially with the balance which should be obtained on-chip. As the local oscillator is "on-channel" this is important.

It is necessary to achieve quadrature local oscillator signals over a relatively wide bandwidth and to operate the two mixers M1, M2 in as matched a fashion as possible. One way to do this is to use a phase locked loop (phase detector PD and amplifier PA), which sets the phase of the locked oscillator LO1 90° from the locking signal—with an error dependent upon the loop gain. The practical system will be required to interface with a synthesiser S for channel selection and so each mixer will have an oscillator—the one, LO2, locked to the synthesiser S via a pre-scale divider PSD and the other oscillator LO1 locked to LO2. They are then identical and, being on one chip will track with temperature and supply voltage variations etc. Additionally both will achieve the same noise sideband performance, within the limits of the loop gain. There are off-chip timing capacitors C1 and C2 for the two oscillators LO1 and LO2.

The low pass filters must be able to handle the entire dynamic range of the system and as shown, i.e. with no RF gain, their loss and noise figure determine the system sensitivity for a given mixer performance. Thus passive LC filters are to be preferred to RC, or active RC filters. Although this means off/chip components, the complexity of the external circuit can be low. For example for 5KHz deviation (i.e. corner) only one coil L and three capacitors C3, C4, C5, are needed to achieve 65 dB rejection to the adjacent channels at 25 KHz. Neither do the components have to have very good unloaded Q in this application.

It is clearly also simple to incorporate filtering of a special kind, e.g. pseudo-gaussian for FSK (frequency shift keyed, i.e. digital) modulation, or to take out wide-band outputs from the mixers M1 and M2 for such things as band scanning or spread spectrum techniques.

The splitting of the circuit at this point whilst 'costing' 4 pins in the integrated circuit form does enable either part of the circuit to be used independently if required.

There are off-chip capacitors C6 and C7 for determining the time constant of the feedback system of the amplifiers G1 and G2.

The differentiators D1 and D2 are each simply realised as a CR network. To give acceptable phase and amplitude response over the baseband the corner frequency of this network needs to be much higher than the top of the baseband-ten times typically. Thus in-band it has a large loss which must be compensated for by an amplifier AD. For maximum flexibility the capacitors e.g. C8, C9 will be off-chip. The four-quadrant multipliers M3 and M4 are conventional transconductance circuits used for this purpose. The critical feature of these is the amount of balance (i.e. rejection of input at the output) obtainable. This balance sets the spurious level at the output. Similarly the balance of the whole system and the common mode rejection ratio of the output amplifier DA determine the level of break-through of any static frequency difference between the signal and local oscillator. That is, such a difference ideally only produces a DC offset in the response, but practically produces a beat note which is rejected by the balance of the circuit. AFC should help this problem. AM rejection is similarly dependent on the balance achieved in the whole processing section. An advantage of integration is that the overall balance should be very good.

Fig. 3 shows an alternative and simplified arrangement for obtaining the local oscillator frequencies in quadrature. Only one local oscillator LO3 is required, feeding two amplifiers A1, A2. The feed to amplifier A2 includes a network 1oR and 1oC the time constant of which is chosen so that it introduces a 90° phase shift in the signal fed to amplifier A2. The operating frequency is chosen to be well above the corner frequency introduced by the network. This implies not only a phase shift approaching 90° but also a reduction in amplitude which is compensated for by amplifier A2. Amplifier A1 is included as a buffer in order to equalise the excess phase shift due to amplifier A2. The outputs LO1 and LO2 drive the mixers M1 and M2 as before.

For the four-quadrant multipliers M3 and M4, instead of the standard transconductance

multiplier, another standard technique using pulse-width modulation may be employed.

One of the signals to be multiplied, e.g. the outputs of D1 and D2 in each case are fed to an operational amplifier, the other input of which receives a sawtooth waveform from a local oscillator. The output of the operational amplifier is a high frequency train of width modulated pulses which replaces the original linear signal from the differentiator. By this means better balance of the system can be obtained without the need for trimming external to the chip.

WHAT WE CLAIM IS:—

1. A demodulator for frequency modulated signals comprising local oscillator means for providing first and second signals in phase quadrature at the centre frequency of the frequency modulated signal, first and second mixing means for respectively mixing the frequency modulated signal with the first and with the second local oscillator signal, means for low pass filtering each of the outputs of the first and second mixing means, means for amplifying each of the outputs of the low pass filtering means to a constant level, means for differentiating each of the outputs of the amplifying means, means for coupling the output of each differentiating means and the input of the other differentiating means to a multiplying means, and means responsive to the difference between the outputs of said multiplying means to provide a demodulated audio signal.

2. A demodulator according to claim 1 wherein the local oscillator means comprises first and second oscillators, said first oscillator providing said first signal, said second oscillator being coupled to said first oscillator by a phase locked loop arrangement and providing said second signal.

3. A demodulator according to claim 1 wherein the local oscillator means comprises a local oscillator the output of which is fed directly as the first signal to the first mixing means and via a phase shifting network as the second signal to the second mixing means.

4. A demodulator according to claim 3 wherein the first and second signals are fed via first and second amplifiers respectively having similar phase shift characteristics but the second amplifier having a greater amount of gain than the first so that the first and second signals fed to the mixing means have the same amplitude.

5. A demodulator according to any preceding claim wherein each amplifying means comprises an automatic level control (ALC) amplifier.

6. A demodulator according to any preceding claim including means for converting one of the signal inputs to each multiplying means from a linear signal to a pulse width modulated signal.

7. A demodulator for FM signals substantially as described with reference to the accompanying drawings.

S. R. CAPSEY,
Chartered Patent Agent,
For the Applicants.

Printed for Her Majesty's Stationery Office, by the Courier Press, Leamington Spa, 1978
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

1530602 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

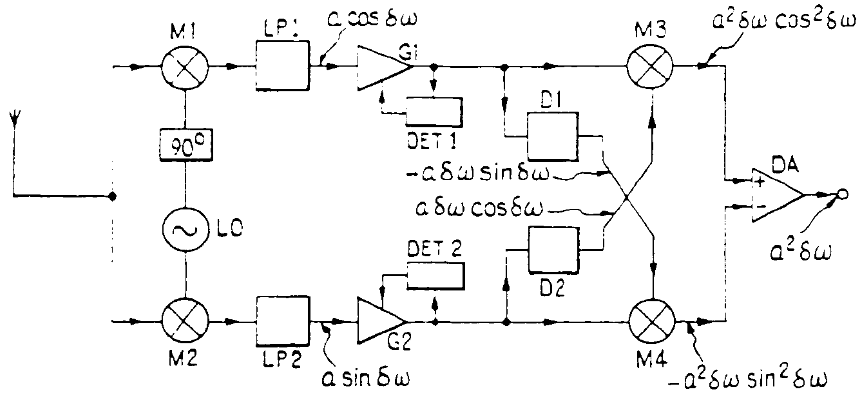

FIG. 1

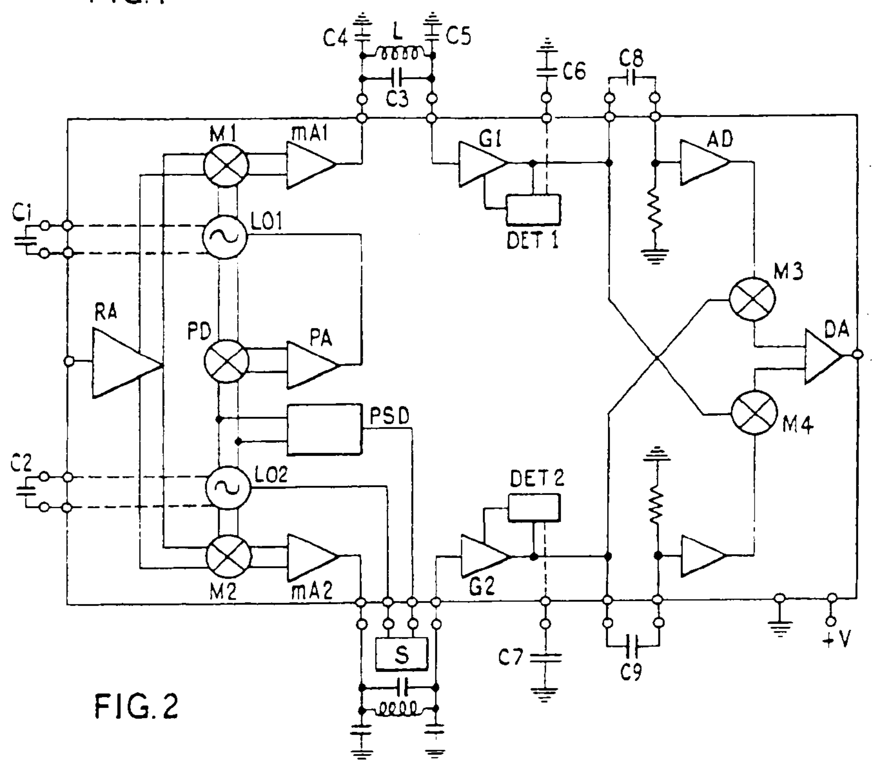

FIG. 2

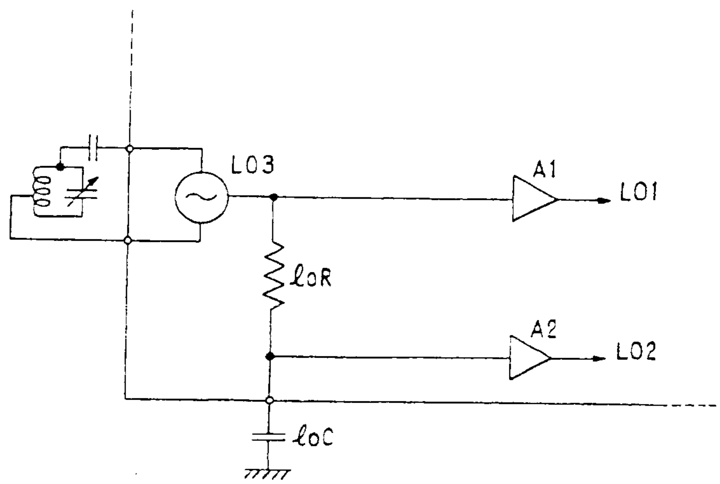

FIG.3

DOCKET NO: 1999P2204

SERIAL NO: ____________

APPLICANT: Stefan Waasen et al.

LERNER AND GREENBERG P.A.
P.O. BOX 2480
HOLLYWOOD, FLORIDA 33022
TEL. (954) 925-1100